The Taxonomy of *Polysiphonia* in Hawaii[1]

ERNANI G. MEÑEZ[2]

ABSTRACT: An investigation of *Polysiphonia* collections from Oahu, Hawaii, Molokai, and Maui of the Hawaiian Islands has revealed the presence of seven species: *Polysiphonia mollis* Hook. & Harv., *Polysiphonia pulvinata* (Roth) J. Ag., *Polysiphonia subtilissima* Mont., *Polysiphonia ferulacea* Suhr., *Polysiphonia yonakuniensis* Segi, *Polysiphonia flabellulata* Harv., and *Polysiphonia rhizoidea* sp. nov. These seven species of *Polysiphonia* were recognized primarily by their morphological features.

Some characteristics of *Polysiphonia* which have not been previously used by monographers but which appear to be important criteria for delimiting specific entities are discussed. One of these is the presence of more than one secondary pit connection between adjacent pericentral cells, a condition present in *P. rhizoidea* and *P. yonakuniensis* but not in the other species mentioned above. The other is the presence of multicellular rhizoids, a condition which was observed only in *P. rhizoidea*. Previously, authors have accepted the rhizoids of *Polysiphonia* as being unicellular.

ALTHOUGH there are a number of published articles on the marine algae of Hawaii, none of them deals specifically or intensively with the taxonomy of *Polysiphonia*. Up to the present, only six species of *Polysiphonia* have been recorded in the literature as occurring in Hawaii: *Polysiphonia aquamara* Abbott, *Polysiphonia calothrix* Harv., *Polysiphonia ferulacea* Suhr., *Polysiphonia mollis* Hook. & Harv., *Polysiphonia polyphysa* Kuetz., and *Polysiphonia tongatensis* Harv.

With respect to the published records of these six species, reference may be made to the works of Chamberlain (1860), Falkenberg (1901), Tilden (1901), Lemmermann (1905), MacCaughey (1918), Yendo (1918), Weber van Bosse (1923), Neal (1930), and Abbott (1947).

The objectives of the present study were to evaluate the validity of these taxa and to determine if additional species of *Polysiphonia* are represented in Hawaii. The species included in this study were recognized primarily by morphological features.

ACKNOWLEDGMENTS

The author is indebted to Dr. Maxwell S. Doty, of the University of Hawaii, Dr. George Hollenberg, of the University of Redlands, California, and Dr. Toshio Segi, of the Prefectural University of Mie, Japan, for their invaluable comments; to Dr. Benjamin Stone, of Guam College, for preparing the Latin description of *Polysiphonia rhizoidea* sp. nov.; to Mr. E. H. Bryan, Jr., and Miss M. Neal for permission to examine the exsicatti materials of *Polysiphonia* in the Bernice P. Bishop Museum; to Drs. Charles Lamoureux and Sidney Townsley, of the University of Hawaii, for their critical reading of this paper; and to the Botany Department of the University of Hawaii, for providing field and laboratory facilities and supplies for this research.

[1] Part of a thesis submitted to the Graduate School of the University of Hawaii in partial fulfillment of the requirements for the degree of Master of Science in Botany, March, 1962. Manuscript received March 8, 1963.

[2] Biology and Botany Department, University of British Columbia, Vancouver 8, Canada.

MATERIALS AND METHODS

The collections of *Polysiphonia* in Dr. M. S. Doty's herbarium (DUH); *Polysiphonia* collections deposited at the Bernice P. Bishop Museum (BISH) by I. Abbott, E. Bailey, J. Rock, D. Rogers, and J. Tilden; and my own collections around Oahu (M) were the materials used in this study.

A. Collection of the Biological Materials

As much area as possible was covered at every station. The materials collected were first placed in plastic bags and later transferred to wide-mouthed bottles filled with 10 per cent formalin.

B. Investigation of the Biological Materials in the Laboratory

Little difficulty was met in the preparation of the materials for the detailed studies. There were three types of preserved materials: old mounted dry specimens, materials preserved in formalin for several years, and fresh collections in 10 per cent formalin.

A drop of water was added to each of the old mounted specimens to make them soft enough to avoid damaging any structures when preparing samples for microscopic study. It was usually necessary to boil such dry specimens for a few minutes to restore the normal cell shape. On the other hand, the old specimens preserved in formalin did not need to be boiled but had to be stained to distinguish the pericentral cells, using 1 per cent aniline blue or 1 per cent safranin O. The newly collected materials were softened in sea water-formalin solution for 24–48 hours before examination.

A dozen or more slides of each collection were prepared. A few thallus fragments were taken from each collection and placed on one or more slides with a drop of 10 per cent glycerine solution.

For counting the number of pericentral cells the materials were either crushed on the slide or cross-sections were cut. Important characteristics of the different species were illustrated with a camera lucida. Measurements were made with an ocular micrometer.

THE GENUS *Polysiphonia*

The genus *Polysiphonia,* established by Greville in 1824, belongs to the family Rhodomelaceae in the Rhodophyta. According to Falkenberg (1901), *Polysiphonia* should include all those radially symmetrical members of the Rhodomelaceae in which (1) at least the ultimate branches are evidently polysiphonous, (2) most of the branches arise exogenously by a more or less diagonal division of subapical cells before these have cut off pericentral cells, (3) all branches are essentially similar and indeterminate, and (4) only one tetrasporangium is borne normally in each segment.

IMPORTANT TAXONOMIC FEATURES

A. Trichoblasts

Rosenvinge (1903) referred to the structure that other investigators have called "leaves" as "trichoblasts." Commonly, one trichoblast occurs on each segment. Hollenberg (1942) commented on the trichoblasts as being usually arranged spirally in a counter-clockwise direction toward the tip of the branch, looking at the branch from the apex. In the present paper this would be referred to as a right-hand spiral. Hollenberg also stated that the divergence of the trichoblasts in the spiral is relatively constant and usually bears some relation to the number of pericentral cells. The trichoblasts may be simple or forked, consisting of one to several segments of cells. They are usually present at or near the apices. Generally, they are deciduous, leaving conspicuous scar cells after they fall off.

B. Branches

In the Rhodomelaceae, Falkenberg (1901) distinguished two types of branches: (1) determinate branches, which do not ordinarily give rise to further branches, and (2) indeterminate branches, those of potentially unlimited growth. The branches are either of endogenous or exogenous origin. Branches arising after the pericentral cells have been formed are designated as "endogenous," whereas those formed before the formation of the pericentral cells are referred to as "exogenous." The branches

of all the *Polysiphonia* species described in this paper are exogenous.

Hollenberg (1942) described two types of exogenous branches: (1) normally exogenous branches, arising directly from the branch primordia, and (2) cicatrigenous branches, developing from the scar cells after the trichoblast has fallen off.

C. Antheridia

The antheridia usually occur as primary branches of the trichoblasts or may occur on the trichoblasts, covering the lower part of the latter. At the apex of each antheridium a sterile tip of one or more cells may be found. Each antheridium is usually supported at the base by a two-celled stalk.

D. Cystocarps

Polysiphonia cystocarps are very variable in shape. They are usually urceolate, ovate, or oblong and seem to be little used for systematic or taxonomic purposes.

E. Rhizoids

The rhizoids occur at the base of the thallus. While they may also be found on the axis above the thallus base they are never found near the thallus apex. The rhizoids may occur singly or several may be produced from a segment of the thallus. They arise as outgrowths from the proximal end or middle of the pericentral cells. They are commonly unicellular, but sometimes multicellular. Each may or may not be cut off by a cross-wall at its proximal end from the supporting pericentral cell. The tip of the rhizoid may be simple, digitate, or discoid.

F. Pericentral Cells and Cortical Cells

In the tetrasiphonous species of *Polysiphonia* (Segi, 1951), the number of pericentral cells is usually constant throughout the entire thallus, while in species with more than four siphons the number of pericentral cells may vary in the different parts of the thallus.

Cortical cells may be observed in some species. They are usually formed near the base of the thallus and arise from the pericentral cells. In these corticate species the rhizoids are produced from the cortical cells. All the *Polysiphonia* species described in this paper are uncorticated.

OBSERVATIONS AND RESULTS

Polysiphonia ferulacea Suhringar *in* J. Agardh, Spec. Alg. II:980, 1863

Figure 1, *A–E*

TYPE: From the Atlantic coast of Mexico, North America, and presumed to be in the Agardhian herbarium, University of Lund.

Thalli up to 5 cm in height, usually shorter.

KEY TO THE HAWAIIAN SPECIES OF *Polysiphonia*

1. Pericentral cells 4 2
1. Pericentral cells more than 4 5
   2. Thalli chiefly erect; segments from as long as broad to 4 times as long as broad 3
   2. Thalli chiefly prostrate; segments half as long as broad ..... *Polysiphonia ferulacea*
3. Rhizoids cut off by a cross-wall from the proximal ends of the supporting pericentral cells 4
3. Rhizoids not cut off by a cross-wall and produced from the central parts of the supporting pericentral cells ..... *Polysiphonia subtilissima*
   4. Thalli rarely longer than 1 cm; segments about as long as broad ..... *Polysiphonia pulvinata*
   4. Thalli more than 1 cm long; segments 2–4 times as long as broad ..... *Polysiphonia mollis*
5. Rhizoids multicellular; thalli less than 1 cm long; forming densely matted cushions ..... *Polysiphonia rhizoidea*
5. Rhizoids unicellular; thalli more than 1 cm long; forming loosely arranged tufts 6
   6. Pericentral cells 6; vegetative axes tapered ..... *Polysiphonia flabellulata*
   6. Pericentral cells 10–12; vegetative axes approximately of equal diameter throughout ..... *Polysiphonia yonakuniensis*

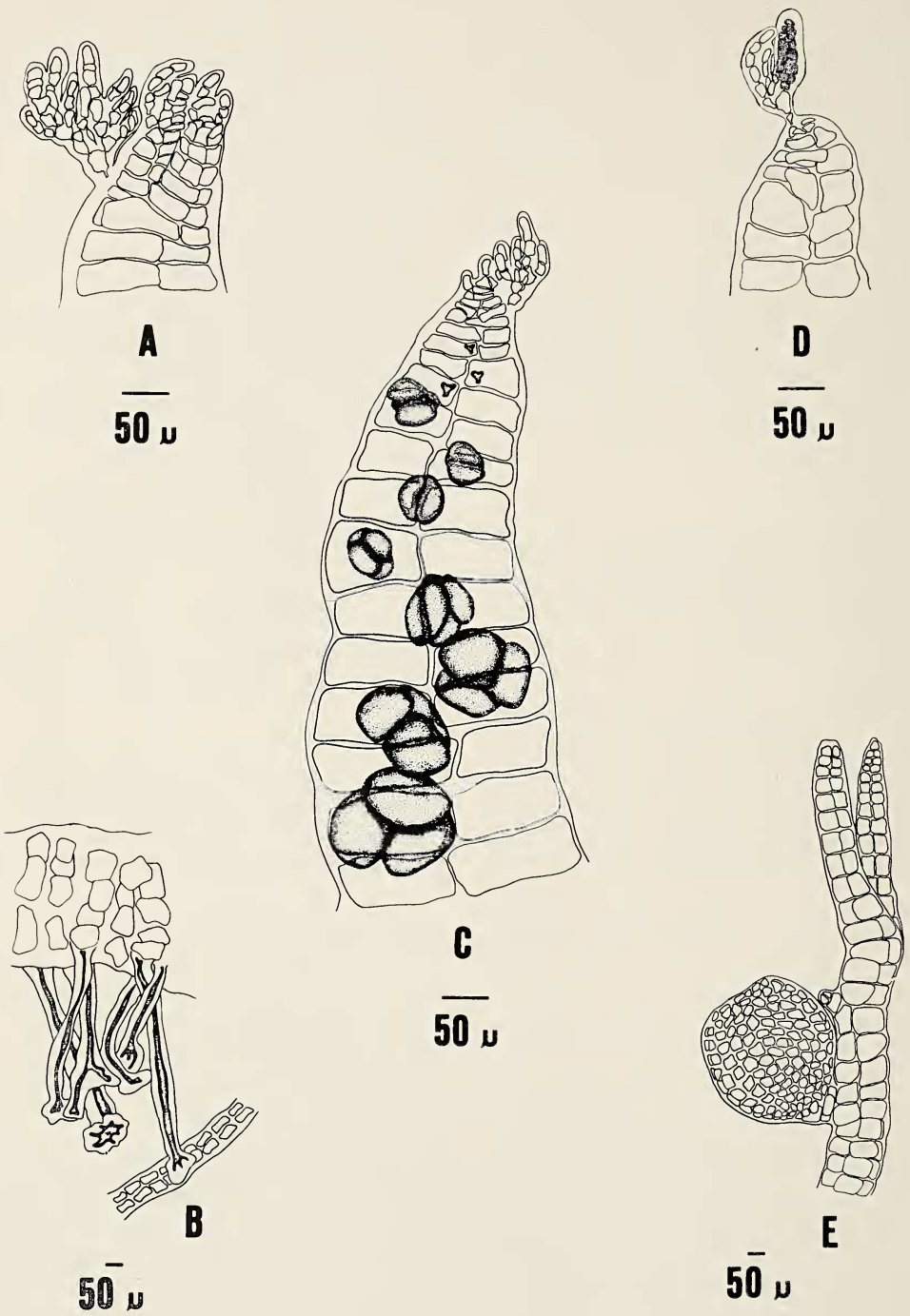

FIG. 1. *Polysiphonia ferulacea* Suhr. *A*, Branch showing trichoblasts. *B*, Rhizoids with disklike and ramified tips. *C*, Branch showing the spiral arrangement of tetraspores. *D*, Apical portion of a branch showing an antheridial cluster. *E*, Branch showing a young cystocarp.

Pericentral cells four, ecorticate. Base composed of a few rhizoids cut off from the proximal ends of the pericentral cells by a cross-wall. Rhizoids frequently one per segment, rarely four in one segment, in some cases robust and less than 1 cm long with disklike terminal ends, in other cases slender and more than 1 cm long with terminal ends ramified into irregularly digitate tips. Rhizoids 25–80 μ in diameter and up to 680 μ long. Vegetative axes about 100 μ in diameter near the apex and up to 546 μ in the basal portion. Segments about half as long as broad. Principal axes dichotomous, angles of dichotomy 40–100 degrees, branches 5–10 segments apart. Short branchlets slightly torulose and recurved. Commonly, some of the exogenous branches arise cicatrigenously. Trichoblasts occur at the branch apices and are 3–5 times forked, up to 780 μ long and 21 μ in diameter, with a robust basal cell about 47 μ broad. Scar cells small, often indistinct, irregularly disposed, one to several segments apart and usually arranged spirally in a ¼ divergence.

Tetrasporangia tetrahedral, 20–35 μ in diameter when mature, produced in the branchlets, one in each segment, arising in a spiral running in a right-hand direction, when the branch is viewed from the point where the oldest tetrasporangium is found and following then toward the branch tip.

Antheridial clusters subcylindrical, developed as primary branches of the trichoblasts, arising from a short stalk. The apex consists of one or two sterile cells enclosed in a thick cell wall.

Cystocarps subglobose to ovate, up to 360 μ in diameter at the widest portion and 470 μ in length, with a narrow opening at the distal end; produced irregularly on the ultimate branchlets.

MATERIALS EXAMINED: *G. Andrews—78* (BISH) & *79* (BISH), from Oahu, and one other with no number, in folder "M" (BISH), collected from Waialua, Oahu, 1876; *E. Bailey—8* (BISH), from Wailuku, Maui; *M. Doty—8141* (BISH, DUH), on concrete wing dam east of Young Women's Christian Association (YWCA) Beach, Waikiki, Oahu, October 7, 1950; *8755* (BISH, DUH), on *Sargassum* devoid of leaves and blackened, collected at Ala Moana Park, Oahu, March 19, 1951; *10999* (BISH, DUH), afloat near Abbott's yard at Laie, Oahu, January 17, 1954; *12439* (BISH, DUH), on reef flat in front of Ala Moana Park, Oahu, April 12, 1954; *12905* (DUH), stiff bristly form afloat at Kalama Park, Maui, July 26, 1955; *12982* (BISH, DUH), tufts on pavement in less than 6 ft of water and also on a red alga apparently belonging to the family Gigartinaceae outside of the breakwater at Maalaea, Maui, August 27, 1955; *13005* (DUH), outside of the breakwater at Maalaea, Maui, August 27, 1955; *17373* (BISH, DUH), on *Sargassum polyphyllum* J. Agardh near the beach close to the natatorium at Sans Souci, Waikiki, Oahu, November 20, 1955; *E. Meñez—713* (BISH, DUH, M), epiphytic on *Acanthophora spicifera* J. Agardh (mixed with *P. mollis*), collected on a reef flat at Waikiki, Oahu, February 24, 1961; *740* (BISH, DUH, M), epiphytic on *Acanthophora spicifera* (mixed with *P. mollis*), collected on a sandy reef flat with limestone rocks in the Old Sugar Mill area, Kaaawa, Oahu, July 7, 1961; *J. Rock*—no numbers (BISH), collected from Waikiki, Oahu, May 8, 1908, April 1908, March 1908; *D. Rogers*—in envelope "R" (BISH), on *Padina* sp., Diamond Head, Oahu, May 21, 1946; *B. Stone—3137* (DUH), afloat at Waikiki, Oahu, January 10, 1959; *J. Tilden—405* (BISH, DUH, M), from Waikiki, Oahu, May 28, 1900 (labelled as being "*P. colensoi* Hook. & Harv.").

Polysiphonia subtilissima Montagne, Ann. des Sci. Nat., Bot. 13:199, 1840b

Figure 6, D–G

TYPE: Type specimen collected from shores of Cayenne, France.

Thalli tufted with decumbent branches, up to 10 cm in height. Pericentral cells four, ecorticate. Base composed of rhizoids arising as protrusions from the central part of the pericentral cells, usually one per segment, occasionally two, with simple and ramified tip, 15–32 μ diameter and up to 680 μ long. Vegetative axes 30–105 μ in diameter. Segments as long as broad. Principal branchlets dichotomous, angles of dichotomy 20–90 degrees, branches 4–20 segments apart, with fewer intervening segments in the base. Commonly, some of the exogenous branches arise cicatrigenously. Occasionally, trichoblasts may be found at the tips and on the vegetative axes, usually one in each

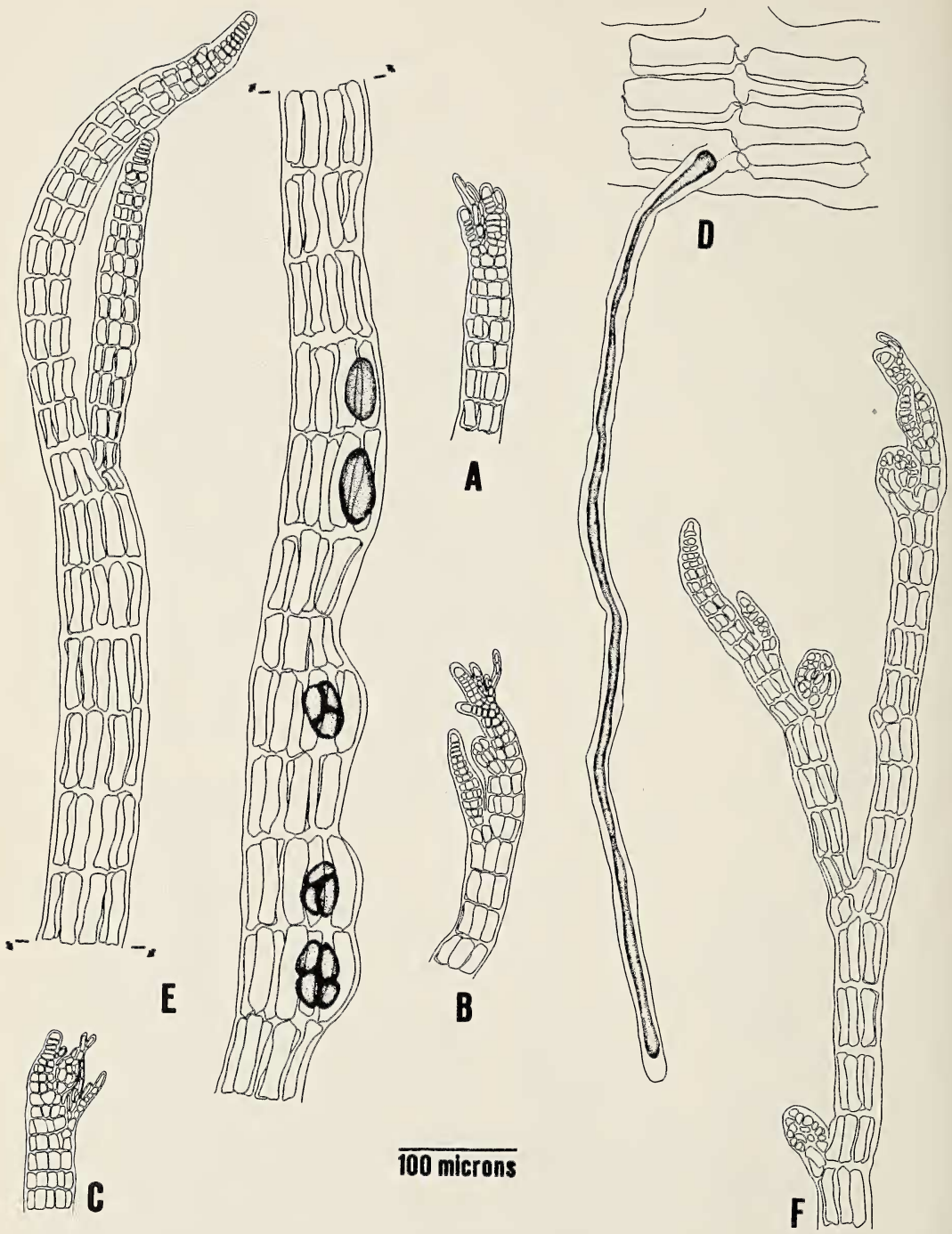

FIG. 2. *Polysiphonia flabellulata* Harv. *A–C,* Branches showing young trichoblasts. *D,* Segment of a basal thallus showing a simple rhizoid. *E,* Branch showing the seriate arrangement of tetraspores (small arrows indicate the point of connection of the two branch-segments flanking *E*). *F,* Branch showing young cystocarps.

segment, twice forked, 5–10 μ in diameter and up to 450 μ long. Basal cells shorter than the rest of the cells above it. Scar cells rare and irregularly disposed.

Tetrasporangia not found in the materials at hand.

Antheridia not found in the materials at hand.

Cystocarps not found in the materials at hand.

MATERIALS EXAMINED: *E. Meñez—710* (BISH, DUH, M), collected in about 3–4.5 ft water from the bank of Waipuhi Stream above Kamehameha Highway (towards the open sea on the sea side of the bridge coming from Kaneohe), Hauula, Oahu, February 24, 1961; *711* (BISH, DUH, M), collected in about 4.5–8 ft water from the bank of Waipuhi Stream at the mountain side of the bridge at Hauula, Oahu, February 24, 1961; *728a* (BISH, DUH, M), on cement wall made with basalt rock along Waipuhi Stream inland from Kamehameha Highway, near Hauula School, Hauula, Oahu, May 13, 1961; *728b* (BISH, DUH, M), on cement wall along ocean side of Waipuhi Stream near Hauula School, Hauula, Oahu, May 13, 1961.

Polysiphonia mollis Hooker and Harvey, Ner. Austr. 2, 8:43, 1847

Figure 3, *A–G*

TYPE: A collection by R. Gunn labelled "original sp." in the Harvey Herbarium, Trinity College, Dublin. Type specimen collected from Tasmania, "parasitical on larger algae."

FACULTATIVE SYNONYMS: *Polysiphonia snyderae* Kylin, Calif. Rhodop., Fysiog. Sallskaplts Hand. 52(2):35, 1941. *Polysiphonia snyderae* var. *intricata* Hollenberg, Amer. Jour. Bot. 29 (9):785, 1942. *Polysiphonia senticulosa* Snyder, *in* Phyc. Bor. Amer. 13:638, 1899. *Polysiphonia eastwoodae* Setchell & Gardner, Mar. Alg. Revill. Is. Exped. 1925. Calif. Acad. Sci. Proc. Ser. 4, 19:161, 1930. *Polysiphonia aquamara* Abbott, Brackish-water algae from Hawaiian Islands. Pacif. Sci. 1(4):212, 1947.

Thalli tufted, up to 12 cm in height. Pericentral cells four, ecorticate. Base of thalli composed of numerous slender rhizoids cut off from the proximal ends of the pericentral cells by a cross-wall, mostly one per segment, with either simple or ramified terminal ends, 20–52 μ in diameter and up to 780 μ long. Vegetative axes about 50–105 μ in diameter near the apices and up to 210 μ in the base. Segments 2–4 times as long as broad. Principal axes dichotomous, angles of dichotomies not more than 45 degrees and 3–14 segments apart, with fewer intervening segments near the apices. Trichoblasts 2 or 3 times forked, arranged in a right-hand spiral on the axis occurring one on each segment, up to 130 μ in length, attenuated towards the apex, basal cell robust and about 10 μ in diameter and much shorter than the rest of the segments above it. Scar cells one on each segment, produced near the apices, and spiralling to the right in a ¼ divergence.

Tetrasporangia 50–115 μ in diameter, tetrahedral, globular, produced near the apices in a spiral running in a right-hand direction, when the branch is viewed from the point where the oldest tetrasporangium is found and following then toward the branch tip.

Antheridial clusters borne as primary branches of the trichoblasts at the apex.

Cystocarps subglobose, stalked, on a segment of 2–4 pericentral cells, 250 μ high and 160–200 μ in diameter.

MATERIALS EXAMINED: *I. Abbott—657* (BISH, DUH), collected from Ualapue Pond, Molokai, August 29, 1944 (labelled *P. aquamara*); *1763* (BISH), collected from Kupeke Pond, Molokai, August 1944 (labelled *P. aquamara*); *1767* (BISH), collected from Maupala Pond, Molokai, August 25, 1944 (labelled *P. aquamara*); *G. Andrews—49* to *52* and *79*, in folder "L" (BISH), collected from Oahu; *E. Bailey*—in folders "K" (BISH) and "E" (BISH) without numbers, collected from Oahu, 1876; *M. Doty—8817* (BISH, DUH), on rocks at 0.0 level in mud on north side of pier of Coconut Island Hotel on shore at Kaneohe Bay, Oahu, April 22, 1951; *12386* (BISH, DUH), on pond connection with muddy bottom, Coconut Island, Kaneohe Bay, Oahu, February 5, 1954; *12389* (DUH), on pond drain, Coconut Island, Kaneohe Bay, Oahu, February 5, 1954; *12684* (BISH, DUH), from a muddy area at Keehi Lagoon, Oahu, December 30, 1954; *12689* (BISH, DUH), Keehi Lagoon, airport side of the largest island (and that island formerly called Mokauea) on Diamond Head side of the runways, Oahu, December 30, 1954; *13078* (BISH, DUH),

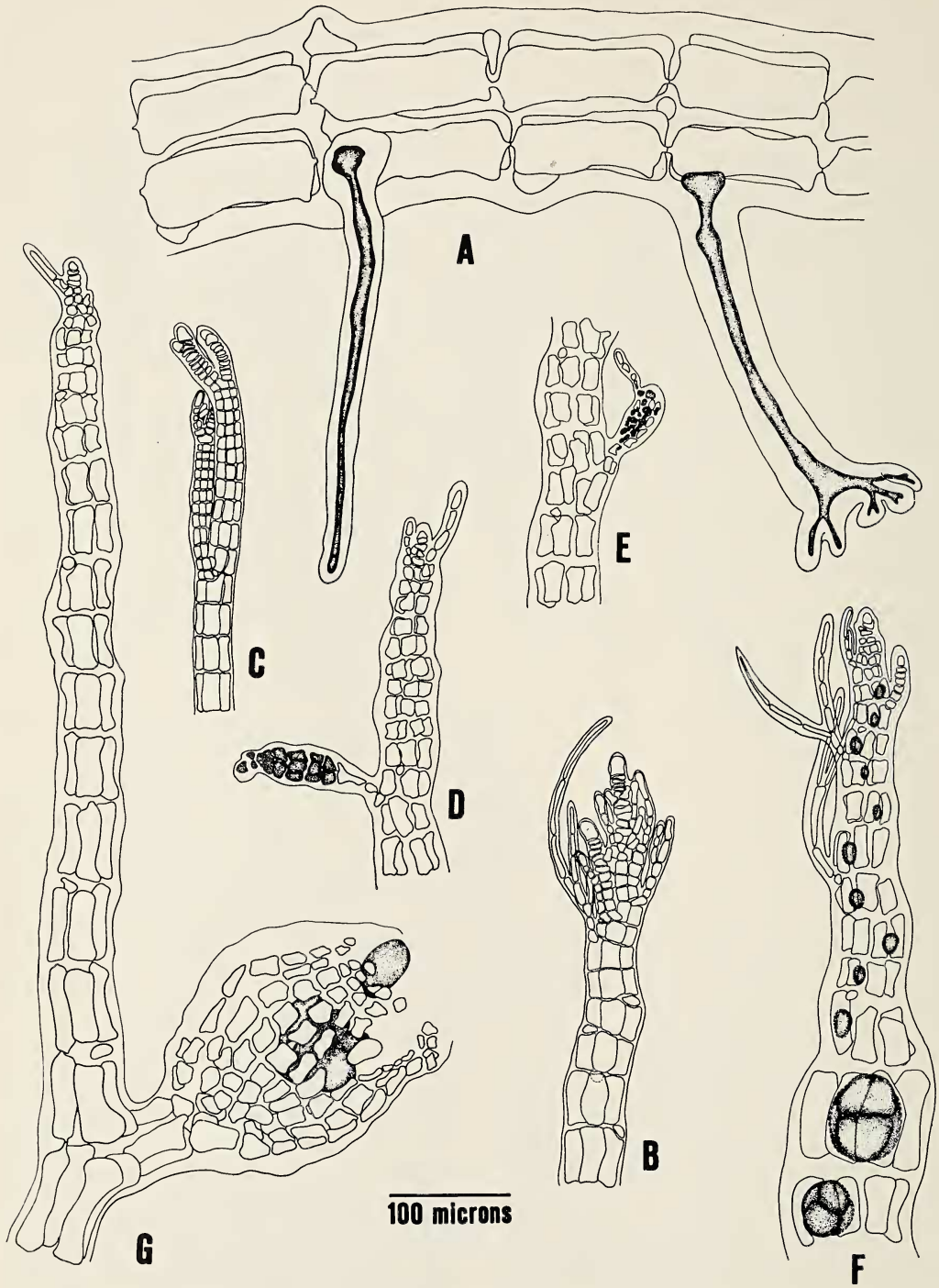

FIG. 3. *Polysiphonia mollis* Hook. & Harv. *A,* Segment of a basal thallus showing a simple and a digitate-tipped rhizoid. *B,* A vegetative branch showing young trichoblasts. *C,* A vegetative branch. *D, E,* Branches showing young antheridial clusters. *F,* Branch showing the spiral arrangement of tetraspores. *G,* Branch showing a mature cystocarp.

collected from muddy shore of Round Pond at Ewa end of Ala Moana Park, Oahu, December 11, 1955; *17161* (BISH, DUH), on the new 1950 flow material at Hookena, Hawaii, January 29, 1953; *17213* (DUH), American Legion Post, Banyan Park, Hilo, Hawaii, February 2, 1953; *E. Meñez—701* (BISH, DUH, M), collected from a sandy-muddy place, on limestone rocks in about 2–4 inches of water continuously flowing at a slow rate, Maunalua Beach area, Oahu, January 29, 1961; *702* (BISH, DUH, M), collected on limestone rocks in about 5–10 inches of water, in a small pool with standing water which is muddy with a little sand, Maunalua Beach area, Oahu, January 29, 1961; *703* (BISH, DUH, M), collected on limestone rocks near the edge of the sandy-muddy shoreline with debris and a few dead animal corals, Maunalua Beach, Oahu, January 29, 1961; *704* (DUH), collected on basalt rocks just below the wall of a pond with turbid water and muddy bottom, Kuapa Pond, in the vicinity of Koko Head, Oahu, January 29, 1961; *705* (BISH, DUH, M), habitat same as *703,* Maunalua Beach, Oahu, February 5, 1961; *712* (BISH, DUH, M), on cement blocks in intertidal level above high-tide line, Sans Souci Beach, Waikiki, Oahu, February 2, 1961; *713* (BISH, DUH, M), epiphytic on *Acanthophora spicifera* (mixed with *P. ferulacea*), collected on a reef flat at Waikiki, Oahu, February 24, 1961; *725* (BISH, DUH, M), collected on concrete block and found growing with other algae near the bridge facing Diamond Head side of Ala Moana Park, Oahu, May 13, 1961; *730* (BISH, DUH, M), algae in thin tufts on limestone rocks covered with mud on banks of Floating Dry Dock area, West Loch of Pearl Harbor, Oahu, May 21, 1961; *731* (BISH, DUH, M), on limestone rocks covered by barnacles and mud, about 500 yards away from collecting area at *730,* Pearl Harbor, Oahu, May 21, 1961; *732* (BISH, DUH, M), on mud-covered oysters, wooden poles, and galvanized iron in a tilapia and mullet fishpond at Kahua Ranch area, Ewa, Oahu, May 21, 1961; *739* (BISH, DUH, M), on top of a concrete block about 1 ft above high-tide line under the bridge at Ala Moana Park, Oahu, May 5, 1961; *740* (BISH, DUH, M), epiphytic on *Acanthophora spicifera* on limestone rocks, on a sandy flat near the Old Sugar Mill area, Kamehameha Highway, near Kaaawa, Oahu, July 7, 1961; *758* (BISH, DUH, M), from a muddy area at Keehi Lagoon, Oahu, February 27, 1961; *J. Rock*—two collections (BISH) with no numbers, one collected from Sand Island, Oahu, June 1, 1908, and another collected from Honolulu waterfront, Oahu, May 30, 1908.

Polysiphonia pulvinata (Roth) J. Agardh, Alg. Maris Medit. et Adriat. 124, 1842

Figure 4, *A–D*

TYPE: Type specimen presumed to be in the Agardhian herbarium, University of Lund.

OBLIGATE SYNONYM: *Conferva pulvinata* Roth, Catal. Bot. I:187, 1797.

FACULTATIVE SYNONYMS: *Hutchinsia pulvinata* C. Agardh, Syst. Alg.:148, 1824. *Hutchinsia badia* C. Agardh, Syst. Alg.: 155, 1824.

Thalli tufted, with decumbent branches, up to 1 cm in height. Pericentral cells four, ecorticate. Base composed of rhizoids cut off from the proximal ends of the pericentral cells by a cross-wall. Diameter of rhizoids up to 25 μ with a length of about 625 μ. Terminal ends simple or ramified, sometimes attached to other filaments or branches, occurring singly, occasionally two or three in each segment. Vegetative axes 78–130 μ in diameter near the apices and up to 210 μ in the base. Segments approximately as long as broad. Principal axes dichotomous, angles of dichotomy not more than 45 degrees. Ultimate branchlets of tetrasporangial plants torulose, attenuated or narrowed towards the base. Cicatrigenous branches common, especially on the basal portions. Trichoblasts numerous at the apices, incurved in immature stages, 500 μ in length and 55 μ in diameter with rounded tips, forked 1–3 times, and arranged spirally in ¼ divergence, deciduous. Basal cell shorter than the rest of the segments. Scar cells one in every segment, arising in a right-hand spiral, with ¼ divergence.

Tetrasporangia 35–55 μ in diameter, tetrahedral, globose, produced one in each segment of the axes near the apex, arising in a spiral running in a right-hand direction, when the branch is viewed from the point where the oldest tetrasporangium is found and following then toward the branch tip.

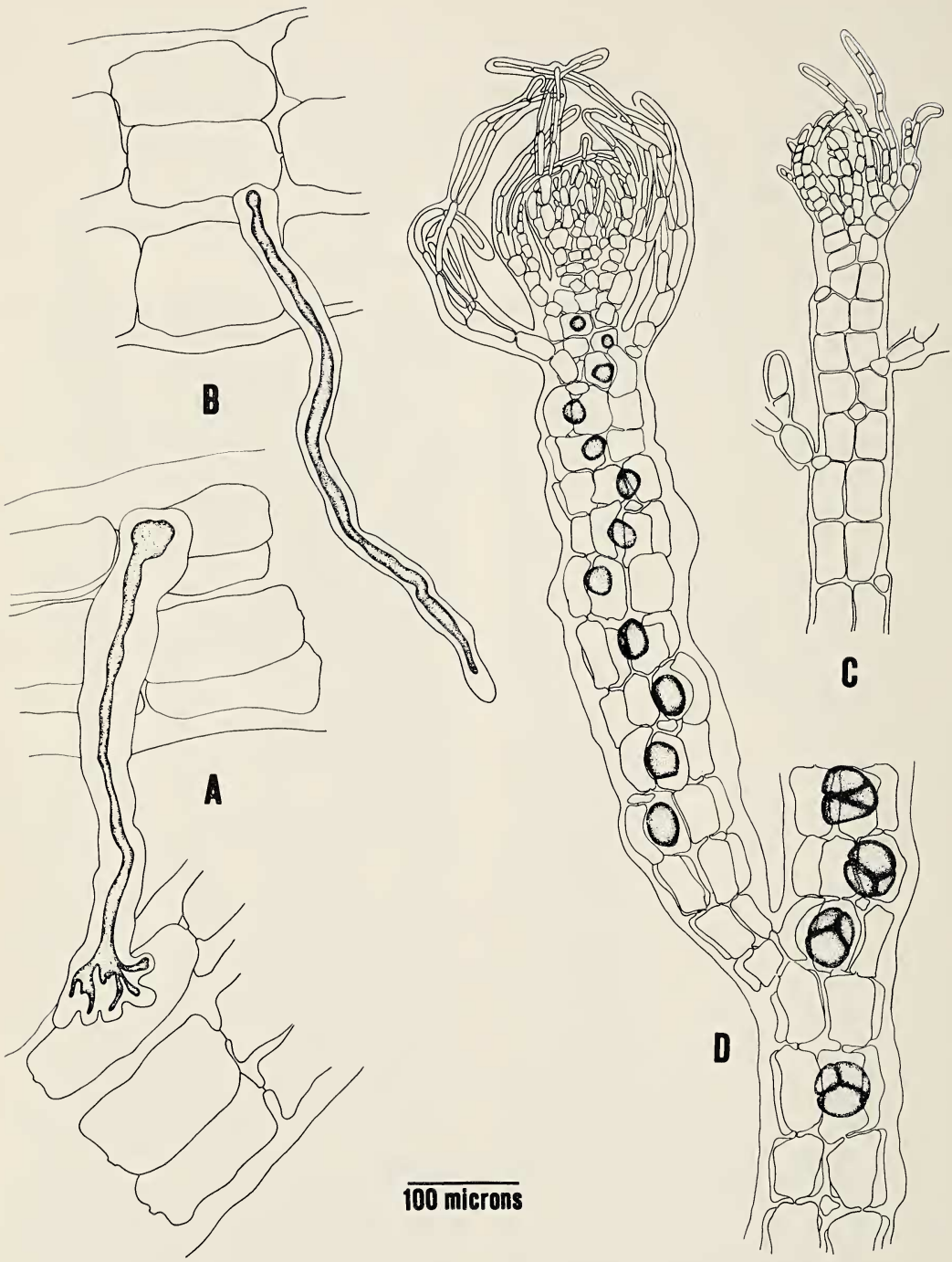

FIG. 4. *Polysiphonia pulvinata* J. Ag. *A,* Basal segment of a thallus showing a rhizoid with ramified tip attached to another branch. *B,* Segment of a basal thallus showing a simple rhizoid. *C,* A branch showing young trichoblasts. *D,* Thallus showing the spiral arrangement of the tetraspores.

Antheridia and cystocarps were not found in the materials at hand.

MATERIALS EXAMINED: *M. Doty—8882* (BISH, DUH), collected on exposed shoulder of lava, Halona, Oahu, May 21, 1951; *12384* (DUH), washed in at Beach Laboratory, Waikiki, Oahu, February 6, 1954; *13549* (DUH), on boulders in sand between low-tide riffle on beach flat and the exposed rock to the east, Kumimi, Molokai, December 29, 1953; *17222* (BISH, DUH), collected at Punaluu Bay, Hawaii, January 29, 1953; *E. Meñez—741* (BISH, DUH, M), collected on limestone rocks in sandy bottom, Mokuleia, Oahu, August 7, 1961.

Polysiphonia rhizoidea sp. nov.

Figure 5, *A–H*

TYPE: *Doty 19256,* on top of prehistoric lava flow dike 6–8 m above high-tide line, about 50 ft east of the 1955 lava flow at Keekee, Puna, Hawaii, December 23, 1959. This number includes antheridial and cystocarpic thalli, of which I designate the antheridial material as the type specimen.

Thalli parvi dense intricati in massos usque ad 1 cm alto, cellulae pericentrales 8–10 cellulis singulis ecorticatis cum 1–3 connectivis aperturalis; basis rhizoidalis rhizoideis 15–55 μ diametro et usque ad 550 μ longis cum partitionis in latere proximale celluli pericentrali; apicibus simplicibus vel disciformibus; ramificationibus nullis vel raribus. Segmentis singulis thallorum unicum rhizoideam emittens; segmentis alteris non rhizoidiferis. Axes vegetativi 52–115 μ diametro, ramis primariis prostratis inconspicuis, ramis secundariis dichotomis vel pseudo-dichotomis (angulis ramificationii 45°–90°); ramulis attenuatis, fere paulo curvatis vel raro recurvatis; segmentis in longitudine quam latitudine 1.5–2 × excedens; ramulis 2–18 segmentis intervenantibus. Trichoblastis subapicalis 2–3 furcatis, 21 μ diametro et 625 μ longis, segmentis apicalis fere quam segmentis basalibus longioris, pedicellis unicellulatis 36 μ diametro. Tetrasporangiis tetrahedralis, globosis, irregulariter dispositis, pseudo-spiraliter vel lineariter seriatis, usque 66 μ diametro; antheriae aggregatis, apicalis, elongatis vel cylindricis, 52 μ diametro, usque 280 μ longis, fere solitariis rare binis in pedicellum unicum. Cystocarpiis globosis vel spheroidalis, breve-pedicellatis, 234 μ diametro et 286 μ altis, aperturis anterioris 57 μ latis; carposporiis clavatis, 68 μ longis et 26 μ diametro.

Thalli forming low, densely matted cushions and not more than 1 cm in height. Pericentral cells 8–10, each with 1–3 secondary pit connections, ecorticate. Base composed of multicellular rhizoids cut off by a cross-wall from the proximal ends of the pericentral cells with simple terminal ends or forming disklike structures, rarely ramified with several short cells, occurring no more than one per segment and several segments apart, 15–55 μ in diameter and up to 550 μ long. Vegetative axes 52–115 μ in diameter, branchlets attenuated, slightly curved, in rare occasions hooked, arising from an inconspicuous primary prostrate branch. Principal axes dichotomous or pseudodichotomous, angle of branching 45–90 degrees, rarely more. Segments about as long as broad, branches 2–18 segments apart. Trichoblasts developed near the apex, rare, 2 or 3 times forked, 21 μ in diameter and 625 μ long, with a short, robust one-celled stalk 36 μ in diameter. Basal trichoblast segments generally shorter than those near the apices. Scar cells rare or wanting.

Tetrasporangia 52–78 μ, tetrahedral, globose, arranged irregularly in the axes, sometimes appearing spiralled in a right-hand direction and in other cases in straight series, up to 66 μ in diameter.

Elongate or cylindrical antheridial clusters, 52 μ in diameter and up to 280 μ long, occurring near the apices of the branches. Some seem to arise as primary branches of the trichoblasts but generally are independent of the latter.

Cystocarps globose or almost spherical, shortly pedicellate, 234 μ in diameter and 286 μ high. Opening at the anterior end narrow, 57 μ. Carpospores clavate, 68 μ long and 26 μ in diameter.

MATERIALS EXAMINED: *M. Doty—13076* (BISH, DUH, M), red-brown to maroon, velvety cushions of an extended sort around high-tide edge of a brackish fishpond at Anaehoomalu, Kona, Hawaii, November 15, 1952; *19256* (BISH, DUH), on top of prehistoric lava flow dike 6–8 m above high-tide line, about 50 ft east of the 1955 lava flow at Keekee, Puna, Hawaii,

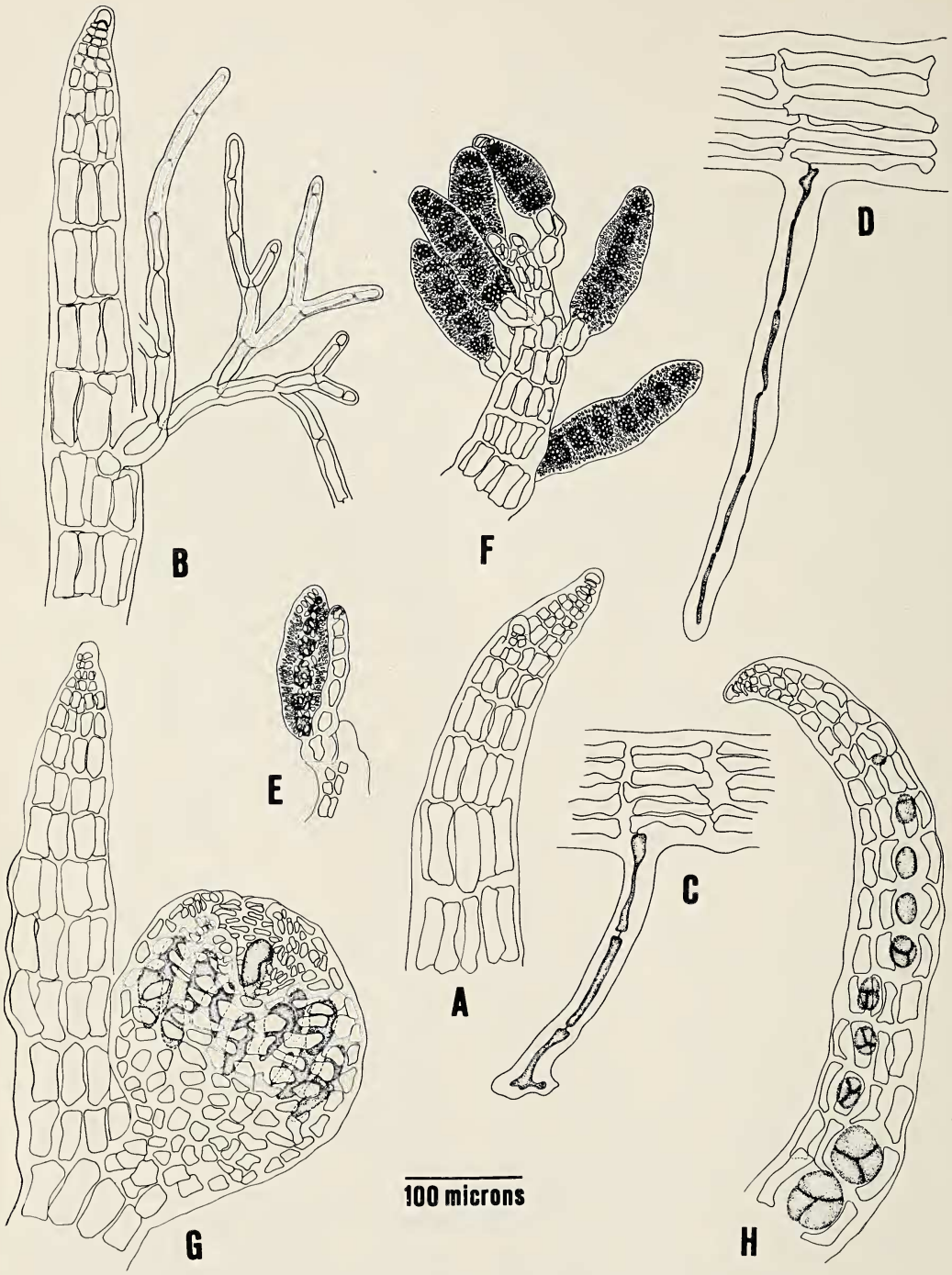

FIG. 5. *Polysiphonia rhizoidea* sp. nov. *A*, A vegetative branch. *B*, Branch showing a trichoblast. *C*, Basal segment of a thallus showing a multicellular rhizoid with a disklike tip. *D*, A multicellular rhizoid with a simple tip. *E*, Branch showing a young and a mature antheridium. *F*, Branch with six mature antheridia. *G*, Branch showing a mature cystocarp. *H*, Branch with tetraspores.

December 23, 1959; *19354* (BISH, DUH), in crevices about 30 ft above high-tide line, in shaded spray-zone situations, ¼ mile east of 1955 lava flow at Keekee, Puna, Hawaii, September 8, 1960; *19357* (BISH, DUH), extensive in spray zone on north facing consolidated cinder at Onomea Cove, Hawaii, September 13, 1960; *19359* (BISH, DUH), spray-zone pahoehoe at Kings Landing, Panaewa, Hawaii, September 13, 1960; *E. Meñez—733* (BISH, DUH, M), on moist clayish soil occurring in densely matted cushions in fishpond area at Kahua Ranch in Ewa, Oahu, May 21, 1961.

This species was found on solidified pahoehoe lava, on moist clayish soil, and binding sand in the bottom of a shaded crevice in pahoehoe. The materials from the exposed condition were collected from a hole on top of a lava-flow dike 6–8 m above high-tide line. On the other hand, the species found on moist clayish soil was collected from the bank of a fishpond, where grasses and other plants grew. These outgrowths were situated in such a way that they covered the area of collection almost completely from sunlight. The first and third habitats mentioned above are located in a spray-zone situation and are not exposed to any degree of wave action except the constant spray of water. On the other hand, the second habitat is entirely devoid of spray. The only supply of water comes from rain and the rise of probably brackish water in the pond. Under all these conditions, the thalli form densely matted cushions.

In the exposed situation, the materials were reddish-purple, whereas the materials in the shaded situation were dull in color. Those in the shaded crevices were slightly dark green in their basal portions but had purplish apices. Those on moist clayish soil were almost as brown as the substratum from which they had been collected.

This species is close to *Polysiphonia howei* Hollenberg from Nassau, Bahamas. Examination of Dr. Doty's collection of *Polysiphonia howei* (No. *19754*) from the Bahamas revealed that the general characteristics and origin of the rhizoids, the curved aspect of some branchlets, the offset position of the pericentral cells in the successive tiers, the presence of 1–3 secondary pit connections, the short basal segments of the trichoblasts, all closely resemble *Polysiphonia rhizoidea* sp. nov. It differs from the latter species in that 1–3 rhizoids occur in a segment, trichoblasts are 2 or 3 times forked and tapered towards the tip, vegetative axes are 55–143 μ in diameter, and pericentral cells number 8–14. *Polysiphonia howei* (No. *19754*) was a sterile specimen.

Polysiphonia flabellulata Harvey, Proc. Am. Acad. IV:330, 1859

Figure 2, *A–F*

TYPE: From Japan. The type specimen is presumed to be in the Harvey Herbarium, Trinity College, Dublin.

Thalli tufted, up to 2 cm in height. Pericentral cells six, ecorticate. Base composed of simple and digitate rhizoids produced from the proximal ends of the pericentral cells. Rhizoids usually one per segment but occasionally four in a segment, whereupon each pericentral cell of the segment produces one rhizoid with a diameter of about 10 μ and a length of 835 μ. Vegetative axes 52–156 μ in diameter, with branches irregularly produced at intervals of 10–20, rarely fewer segments apart. Segments as long as broad, particularly in the ultimate branchlets. Principal axes dichotomous, angles of dichotomy 10–45 degrees. Trichoblasts produced near the apices, 2 or 3 times forked, diameter 6–12 μ, about 55 μ in length, segments as long as broad. Scar cells rare or wanting and irregularly disposed.

Tetrasporangia 45–60 μ in diameter, tetrahedral, oblong, 25 μ in diameter and arranged in a straight series.

Antheridial branches produced as primary branches of the trichoblasts.

Cystocarps subglobose, developed irregularly on the primary and secondary axes, about 160 μ in diameter at the widest portion and 210 μ in length.

MATERIAL EXAMINED: *M. Doty—10820* (DUH), Kaneohe Bay, Oahu, October 10, 1953.

Polysiphonia yonakuniensis Segi, Jour. Fac. Fish. Pref. Univ. Mie 1(2):257–259, 1952

Figure 6, *A–C*

TYPE: Yonakuni Island, Loochoo Islands (T.

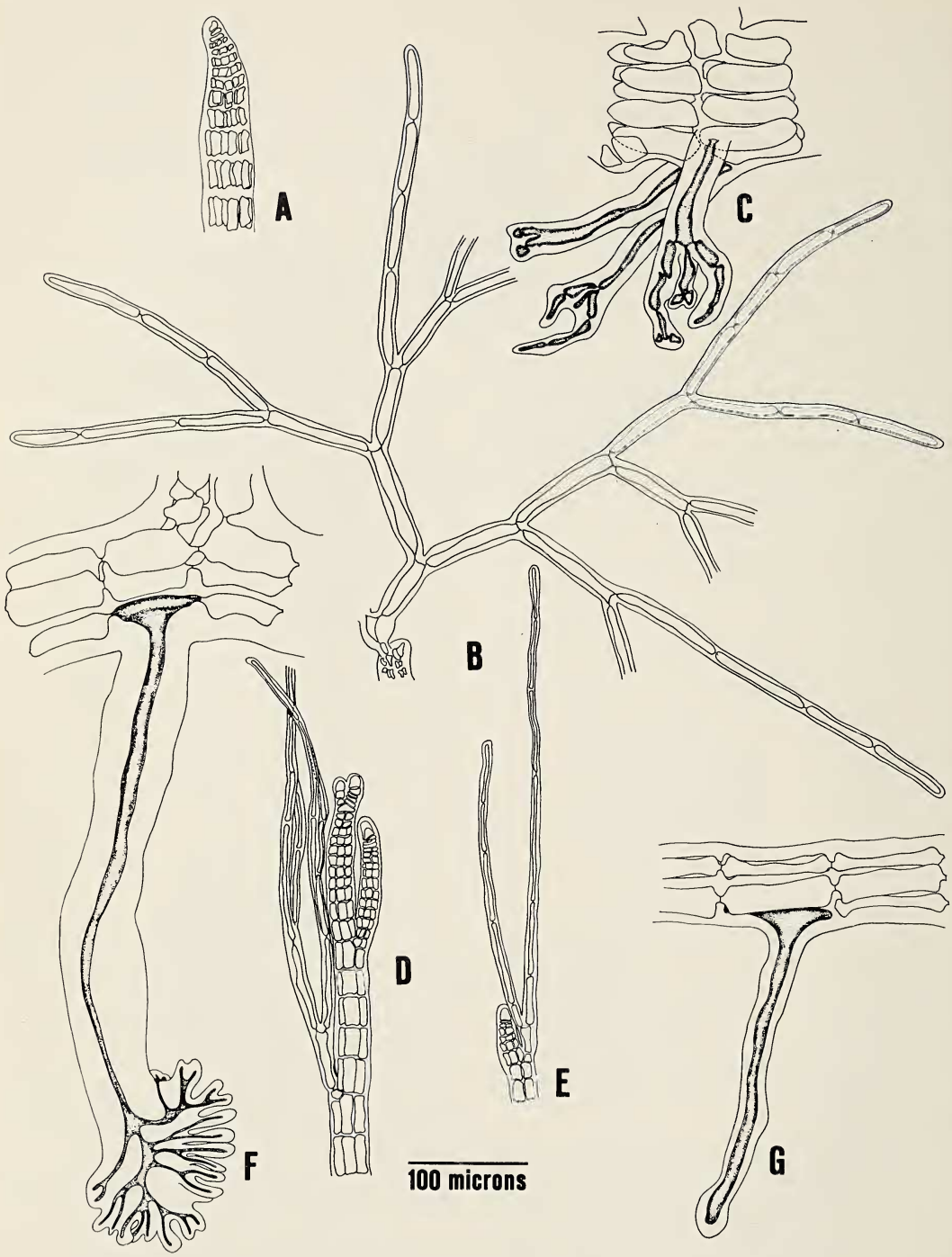

FIG. 6. *A–C, Polysiphonia yonakuniensis* Segi. *D–G, Polysiphonia subtilissima* Mont. *A,* A vegetative branch. *B,* Apex of a branch with a trichoblast. *C,* Basal segment of a thallus showing rhizoids with branched-segmented tips. *D, E,* Branches showing trichoblasts. *F,* Segment of a basal thallus showing a rhizoid with digitate tip. *G,* Basal segment of a thallus showing a simple rhizoid.

Tanaka). Specimen presumed to be in Dr. Yukio Yamada's herbarium at Hokkaido University, Sapporo, Japan.

Thalli up to 2 cm in height, forming densely erect branches arising from a prostrate system. Pericentral cells 10–12, each with one to several secondary pit connections, ecorticate. Base composed of rhizoids cut off by a cross-wall from the proximal ends of the pericentral cells, occasionally branched. Terminal ends disklike when in contact with other filaments or branches of *Polysiphonia* and other algae and simple when free; diameter about 22 μ and up to 575 μ long. Vegetative axes more or less equal in diameter from the base to the segment near the apex. Branches 2–10 segments apart, rarely with as many as 20 intervening segments. Ultimate branchlets slightly recurved. Principal axes irregularly dichotomous, angle of branching 40–80 degrees. Cicatrigenous branches common, particularly on the creeping portion and occasionally on the erect axes. Trichoblasts developed on the axes and apices, 2–5 times forked, 10–32 μ in diameter and 625 μ long. The first two segments of the base shorter than the rest, swollen in appearance in comparison to the upper segments, the cells of which have parallel walls. Scar cells small, occurring irregularly at intervals of two or three segments, with ⅓ to ¼ of a spiral turn in a right-hand direction between them.

Tetrasporangia, antheridia, and cystocarps were not found in the materials at hand.

MATERIALS EXAMINED: *M. Doty—10816* (BISH, DUH), collected just below the upper edge of a nip, forming dense turf patches 3 × 2 × 5 inches, Kapoho Point, Kailua, Oahu, October 10, 1953; *J. Tilden—508* (BISH, DUH), collected at Laie Point, Koolauloa, Oahu, June 16, 1900 (labelled *P. calothrix*); *602* (DUH), collected at Laie Point, Koolauloa, Oahu, June 1900 (labelled *P. calothrix*).

DISCUSSION

Of the six species of *Polysiphonia* previously recorded as occurring in the Hawaiian Islands, I examined exsiccate materials of *P. aquamara, P. mollis, P. calothrix,* and *P. ferulacea* deposited in the herbarium of the B. P. Bishop Museum. I was not able to find specimens of the other two species reported from Hawaii: *P. polyphysa* and *P. tongatensis.*

A specimen in Tilden's collection labelled "*Polysiphonia colensoi* Hook. & Harv.," deposited at the Bishop Museum, seems to agree well with the description of *P. ferulacea* and therefore is cited here as such. It was used as basis for Tilden's report of *P. colensoi* for Hawaii.

Though unable to locate the type of *Polysiphonia aquamara* Abbott, and basing my observations entirely on the materials of this species sent to me by Dr. I. A. Abbott and on two other specimens deposited by her in the Bishop Museum, I conclude that these three collections of *P. aquamara* are not specifically distinct from the species I am calling here *P. mollis.* They agree well with the description of *P. mollis* in this paper and are therefore cited here as such. A personal communication (Abbott, December 15, 1961) indicated her records show that she deposited the type specimen (her No. 1535) of *P. aquamara* in the Bishop Museum. According to Miss M. Neal, curator of the herbarium, and Mr. E. H. Bryan, curator of collections at the Museum, no record exists of this specimen having been received.

Re-examination of Tilden's collections of *P. calothrix* (Nos. 508, 602) revealed that they are not distinct from *P. yonakuniensis* as this species is described in this paper. Comparisons of the descriptions for *P. calothrix* and *P. yonakuniensis* led the author to regard Tilden's collection of *P. calothrix* from Hawaii as a form of *P. yonakuniensis.* The only satisfactory disposition, therefore, seems to be the citing of these collections (Tilden Nos. 508, 602) as *P. yonakuniensis.*

The seven species of *Polysiphonia* described in this work were recognized primarily by their morphological features using Hollenberg's (1942) criteria for distinguishing specific entities in *Polysiphonia.* In addition, two other characteristics of *Polysiphonia,* which have not been previously used by monographers but which appear to be important criteria for delimiting the Hawaiian species of *Polysiphonia,* have been utilized. One is the presence of more than one secondary pit connection between adjacent pericentral cells, a condition present in *P. rhizoidea* and *P. yonakuniensis* but not in the other species

included in this study. The other characteristic is the presence of multicellular rhizoids. Previously, insofar as I know, all authors have accepted the rhizoids of *Polysiphonia* as being unicellular. Multicellular rhizoids were observed only in *P. rhizoidea.*

REFERENCES

ABBOTT, I. 1947. Brackish-water algae from the Hawaiian Islands. Pacif. Sci. 1(4):210–212.

CHAMBERLAIN, J. 1860. Algae of the Hawaiian Islands. Thrum's Hawaiian Almanac and Annual for 1861, pp. 32–33.

FALKENBERG, P. 1901. Die Rhodomelaceen des Golfes von Neapel. Flora und Fauna des Golfes von Neapel. Berlin 26:111–153.

GREVILLE, R. 1824. Scottish cryptogamic flora. Edinburgh, pp. 61–121.

HOLLENBERG, G. 1942. An account of the species of *Polysiphonia* on the Pacific Coast of North America. I. Oligosiphonia. Amer. Jour. Bot. 29(9):772–785.

LEMMERMANN, E. 1905. Die algen flora der Sandwich-Inseln. Bot. Jahrb. 34(5):607–663.

MACCAUGHEY, V. 1918. Algae of the Hawaiian Archipelago II. Bot. Gaz. 65(2):148.

NEAL, M. 1930. Hawaiian marine algae. B. P. Bishop Mus. Bull. 67:71–72.

ROSENVINGE, L. 1903. Sur les organs piliformis des Rhodomelaceae. Bull. de l'Acad. des Sci. de Denmark: 4.

SEGI, T. 1951. Systematic study of the genus *Polysiphonia* from Japan and its vicinity. Jour. Fac. Fish. 1(2):1–272.

TILDEN, J. 1901. Collection of algae from the Hawaiian Islands. Thrum's Hawaiian Almanac and Annual for 1902, pp. 106–113.

WEBER VAN BOSSE, A. 1923. Listes des algues du Siboga. Sib. Exped. Monog. 59(c):357.

YENDO, K. 1918. Notes on the algae new to Japan. Bot. Mag. 32(380):75–77.